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The Use of Chlorates for the Eradication of Certain Perennial Weeds in Utah

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THE USE OF CHLORATES FOR THE ERADICATION OF CERTAIN PERENNIAL WEEDS IN UTAH

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INTRODUCTION

Perennial weeds have retarded agricultural progress, since their first appearance in cultivated fields. They have grown and survived the destructive efforts of the farmer and agricultural scientist, over a great period of time. Many farmers have become discouraged and much valuable land has lain idle because of this wasteful weed persistence.

These dismal consequences have stimulated constant effort at experimental stations to discover more effective methods of battling the pest. The use of chemicals has been one of the most prominent weapons and, of the most recent chemicals tried, the chlorates are the most promising.

REVIEW OF THE LITERATURE

Attempted weed eradication with chemicals has been in process since the latter part of the 19th century. A variety of chemicals, most of which have been somewhat unsuccessful, has been tried in numerous cases and under varied conditions. The list includes $(NH_4)_2\ SO_4$, H_2SO_4, oils, $Cu\ SO_4$, $NaH\ As\ O_3$, $Fe\ SO_4$, $Na\ Cl$, CS_2, $Na\ NO_3$, NaCn, $Na\ CNS$, $Hg\ Cl_2$ and probably some others. In the eradication of perennial weeds, most of these have a handicap which keeps them from mitigating or solving this problem. They are too expensive, highly poisonous, ineffective, or cause a lengthy impairment of the soil for crop production.

The last five years well include the work done with chlorates. Their favorable qualities have stimulated much research work during this

time, much of which is still in progress.

Regarding the amount of chlorates necessary to eradicate various weeds it has been reported(1), (2), that Canada thistle was eradicated with 183 pounds of Na Cl O_3 or 229 pounds of K Cl O_3, an acre; in another case(5), with 3 pounds a square rod with a possible second application the following spring. Other workers(9) report that in certain cases 3 pounds on a square rod did the job while another investigator(6), (7), states that 6 pounds in two applications were necessary for its complete eradication. Morning glory(3), (4) has been abolished with three 100-pound-to-the-acre applications of Na Cl O_3; three (6), (7), 2-pounds-to-the-square-rod application; in some cases(9), with 3 pounds to the rod, and (5) with 3 pounds to the square rod with a possible second application the following spring. Quack grass(6), (7) was reported killed with three 2-pound-to-the-square-rod applications of Na Cl O_3. Johnson grass(8) has been controlled with two 100-pounds-to-the-acre applications. Russian knapweed(9) has been eradicated in some cases with 3 pounds to a square rod, and White Top in some instances with 4 to 4½ pounds to a square rod.

With reference to time of application it has been found(2), (5), (8), (9), that late summer and fall sprayings seem better than earlier ones. On the other hand, Willard(6) found early sprayings the best, and Latshaw and Zahnley(3) noticed an advantage by spraying when the plant was in full bloom.

In regard to the chemical effect on the soil, Aslander(2) and Hulbert, Remsberg, and Spence(9) conclude that crops can be successfully grown the season following treatment. Severe injury was noted(5) on a wheat crop planted immediately after treatment, and the killing of an oat crop(8) was observed on land which had received Na Cl O_3 at the rate of 200 pounds to the acre.

With reference to the condition of the weed at time of treatment some investigators(8), (10) have obtained good results by treating after the weed had regrown 8 or 12 inches from a previous cutting. Others(9) state emphatically

the importance of not disturbing the weed either before or after treatment.

Chlorates have been used in some cases for the eradication of weeds in lawns and pastures. Welton(11) successfully controlled ground ivy(Glecoma hederacea) and Thyme-leaved Speed-well(Veronica serpyllifolia) in lawns with Na Cl O_3 at the rate of 2 ounces on 100 square feet, applied in solution as a spray. Aldous(12) killed 78 per cent of the sumac stems(Rhus globra) in pastures, with a 100-pound-to-the-acre application of Na Cl O_3, but also severely injured the forage plants, showing its use in this manner to be decidedly impractical.

EXPERIMENTAL PROCEDURE

The experiment was carried out on some typical weed patches in representative farming sections throughout three important agricultural counties of the state. Particular attention was paid to securing areas which were densely and uniformly covered(Fig.1) so that the chemical was subjected to the weed in its most resistant natural condition. The areas were definitely secured for two years or longer, making possible a thorough observation of the ultimate weed-destroying power of the chemical.

The weeds involved represent a number of those most injurious in the state agriculturally; viz., morning glory(Convolvoul arvensis), Russian knapweed(Centaurea picris), Canada thistle(Circum arvense), and perennial sow thistle(Sonchus arvensis). Morning glory, one of the worst of these, especially infesting the more valuable land, was exposed to the chemical in six widely separated areas in the three counties, representing practically so many soil types. Each of the others was subjected to the tests in an area representing the conditions under which each most abundantly and persistently thrives.

Two chemicals, i.e., sodium and calcium chlorate, were given the whole attention in this experiment; and of the two, the greater concern

Fig.1.- One of the fields of morning glory before treatment.

Fig.2.- The same field of morning glory as seen in Figure 1, the following spring. The area of growth in the center of the picture to the right is a check plat. To the left of this and in the foreground of the picture Na Cl O_3 was applied at the rate of 3 pounds to the square rod. To the right of the check plat and directly back of it various treatments of $Ca(Cl\ O_3)_2$ can be observed.

attended that of $Ca(Cl\ O_3)_2$ because it lacks, to a great extent, the fire hazard which accompanies the sodium salt.

The design of treatments used in the experiment embodied an arrangement of manipulations which, it was hoped, would deliver information on the following problems:

(1) The amount of sodium chlorate or calcium chlorate necessary to eradicate various weeds, incidentally determining the effect of various amounts of the chemical, especially calcium chlorate, on each.

(2) The influence of time of application, involving tests from June of 1929 to October of the same year.

(3) The comparative effectiveness of the two chemicals for weed eradication which demanded identical tests of the two compounds under the same conditions, in each of the nine fields included in the work.

(4) The significance of method of application, determining the effectiveness of equal treatments applied with a hand sprayer, power sprayer, sprinkling can, and the direct spreading of the powder over the plat.

(5) The effect of concentration of solution, which involved treatments of three specific concentrations: i.e., 3 pounds in 3 gallons of H_2O, 3 pounds in 4 gallons, and 3 pounds in 6 gallons of H_2O.

(6) The difference in the various plants' reaction to the chemical, determining the comparative resistance existing among them.

(7) What effect the disturbance of the plant before treatment has on the effectiveness of the chemical, compared to treatments on plants in their natural undisturbed condition of growth. This work involved the removal of the vegetative growth of the plant before treatment was made.

(8) What effect the application of the chemical at intervals has, as compared to the same amount applied at once, on its ability to prevent plant growth.

(9) What is the nature and extent of the chemical injury to the soil, as determined by planting various crops on certain of the treated areas.

EXPERIMENTAL TECHNIQUE

In all cases but one, two-thirds of a square rod constituted the size of plat used. The exception was a morning glory field sprayed with a power sprayer, wherein the plats were 1½ square rods.

The number of plats on each field ranged from 36 to 48, the latter being the number employed in all cases except two which had 36 and 38, respectively. Each treatment was duplicated on each field, except where note of exception to this is made throughout the presentation of the data. The number of treatments on each field then ranges from 18 to 24 -- the latter being the number in all cases except two.

All treatments were made on a square rod basis.

The following is a detailed plan of treatments, together with a diagram of one of the fields. This plan of treatments, with certain additions in some cases, formed the basis of the work on the nine fields included in the experiment.

Plat No.

1 and 25 -- 1 lb. per gal.; 3 gals. per sq. rd. $Ca(ClO_3)_2$
2 " 26 -- 1 " " " ; 3 " " " (in 3 applications of 1 gal.each)
3 " 27 -- ½ " " " ; 3 " " "
4 " 28 -- ¼ " " " ; 6 " " "
5 " 29 -- ¼ " " " ; 3 " " "
6 " 30 -- ¼ " " " ; 4 " " "
7 " 31 -- 1½ " " " ; 3 " " "
8 " 32 -- 2 " " " ; 3 " " "
9 " 33 -- check plats
10 " 34 -- 1 lb. per sq. rd. $Ca(Cl\ O_3)_2$ powder
11 " 35 -- ½ " " " " " " "
12 " 36 -- ½ " " " " " " " ½ lb. 10 days later
13 " 37 -- 1½ " " " " " " "
14 " 38 -- 2 " " " " " " "
15 " 39 -- 1 lb. per gal; 3 gals. per sq. rd. $Ca(Cl\ O_3)_2$ fine mist
16 " 40 -- 1 " " " ; 3 " " " " " " very fine mist can
17 " 41 -- 1 " " " ; 3 " " " " " " Applied with sprinkling?
18 " 42 -- check plats
19 " 43 -- 1 lb. per gal; 3 gals. per sq. rd. $Ca(Cl\ O_3)_2$ at full bloom stage
20 " 44 -- 1 " " " ; 3 " " " " " " 10 days after bloom stage
21 " 45 -- 1 " " " ; 3 " " " " " $Na\ Cl\ O_3$
22 " 46 -- ½ " " " ; 6 " " " " "
23 " 47 -- 1½ " " " ; 3 " " " " "
24 " 48 -- $H_2\ SO_4$ -- 8 per cent sol.; 3 gal. per sq. rd.

1	2	3	4	5	6	7	8
16	15	14	13	12	11	10	9
17	18	19	20	21	22	23	24
32	31	30	29	28	27	26	25
33	34	35	36	37	38	39	40
48	47	46	45	44	43	42	41

12 x 15 feet constituted the dimensions of each plat in the field

METHOD OF COLLECTING DATA

Various methods of collecting data have been used by different investigators in weed control. The following procedure was employed in this experiment:

To secure a representation of each field in its normal growing condition, making it possible to determine the effectiveness of each treatment, four check plats were situated at uniform intervals throughout each particular set of treatments.

The average number of weeds on these check plats represented 100 per cent growth, and the percentage of kill with each treatment was determined in direct proportion to this standard. The number of weeds on the check plat and on plats displaying a poor kill was obtained by counting the weeds on two 4-square-rod areas located equidistant from two diagonal stakes on each plat. In noting the progressive kill of the weed the investigator located and counted these exact areas at the various intervals. A count of weeds on the whole plat was taken when the effectiveness of the chemical made it possible to do so with accuracy.

EFFECT OF VARIOUS AMOUNTS OF $Ca(Cl\ O_3)_2$ ON FIVE WIDELY SEPARATED MORNING GLORY PATCHES

It is likely that the most important single factor in the problem emerges from the question of how much chemical is necessary to eradicate a particular weed on a specific area of land. This is the first knowledge an interested farmer wants, for herein lies the answer to the ever acute question of how much expense is involved. After this point is made clear he will probably desire, provided the cost of the chemical is within reason, information on method and time of application, etc.

Endeavoring to find the minimum amount of chemical which would give the most satisfactory and economical results, the investigator applied treatments, ranging from one-half pound to 6 pounds a square rod on morning glory in five

different places throughout the three agricultural counties.

From the data at hand(Table 1) it is evident that in general the more chemical applied on a given area, the greater is the percentage kill. The range of difference was between 49 per cent kill for the one-half pound application and 97 per cent kill for those of 6 pounds. The increase in percentage kill, however, is not proportional to the increase in chemical applied; for the average of the 2-pound applications is 91, only 6 per cent lower than the average percentage kill of the 6-pound treatments. This latter point is strikingly represented in the results of the first three fields of the table which show that the 2-pound and 6-pound applications are almost equal in effectiveness. In the remaining two fields a somewhat different situation exists. Here it will be observed that the increase in percentage kill is more gradual and more nearly proportional to the increase in chemical applied. Data pointing to an explanation of this will be taken up under the heading, "Time of Application and Soil Type".

From the results of this range of treatments then,which amount should be recommended for practical use? Six pounds to the square rod, the highest amount employed in the experiment, did not, under all conditions, give a 100 per cent kill; it is therefore, with the present data, impossible to state an amount which would insure complete eradication of the morning glory.

Although it is realized that one or two plants left on a plat represent a potential reinfestation of the field, it is believed economical to use a lighter application and spend the money which would have been needed for extra chemical in the heavy application, on a second application or in the physical elimination of the weeds left by a more vigorous and persistent hoeing, while growing a cultivated crop the following season. This also has the advantage of a reduced soil effect, for it has been observed that the more chemical applied, the greater is the toxic effect on the growth of subsequent crops.

Table 1. Results of various amounts of Ca Cl O_3 on five widely separated morning glory patches sprayed at various times

Pounds of Chemical to the Square Rod	Percentage Eradication					
	Field No.1: Gravelly Loam: Sprayed June 25	Field No.2: Clay Loam: Sprayed July 9	Field No.3: Silt Loam: Sprayed August 26	Field No.4: Gravelly Loam Sprayed: September 16	Field No.5: Silty Clay Loam Sprayed: October 26	Avg. Percentage Eradication of Each Treatment
½	—	97	52	0	50	48
1	97	97	94	66	50	80
1½	—	93	97	36	50	69
2	98	100	99	84	75	91
2½	99*	96	99	88	—	95
3	99	97	99	98	90	93
4½	100	100	99	98	90	97
6	100	100	100	99	88	97
Average Percentage Eradication on each Field	99	97	92	69	69	

*Results from one plat

It is valuable to note in connection with this that a 15 per cent kill (Table 2) occurs over the winter as an average from all treatments on the five fields. It is further interesting to see that the greatest influence of the winter occurs in the lighter treatments. One-half pound to the square rod gave a 24 per cent kill over the winter; 1 pound, 19 per cent; 1½ pounds, 36 per cent; 2 pounds, 13 per cent; 2½ pounds, 16 per cent; 3 pounds, 10 per cent; 4½ pounds, 7 per cent; and 6 pounds, 2 per cent. As the amount of chemical is increased the percentage of kill over the winter decreases. The seasonal effect of the winter(therefore) works more for our economic benefit in the lighter applications.

TIME OF APPLICATION AND SOIL TYPE ON MORNING GLORY

Results of treatments on fields Nos. 4 and 5 of Table 1 are worthy of specific note. In all cases the treatments are less effective than in the preceding three fields.* Sixty nine per cent represents the percentage kill of the various treatments on each of these two fields, whereas on fields Nos. 1, 2, and 3, the average percentage kills are respectively 99, 97, and 92.

The explanation of this lies in the possible activity of a number of variables, the most important of which are perhaps: time of application, or stage of growth the plant was in when chemical was applied, and soil type. No precise empirical data are available to show exactly which one of these is influential, or how much, in producing the manifested condition. The data at hand indicate, however, that time of application may account for some of this difference.

The variation in soils in the first three fields is considerable, and yet the percentage kills are almost identical. The soils in the two

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*A note of explanation is needed in reference to the data, from field No.4 presented in Table 1. The low percentage kill obtained here may be due in part to a growth of the weed from seeding morning glory which appeared over the area in the spring.

Table 2. Progressive effect of the chemical over the succeeding winter and summer, on the five fields of morning glory of Table 1

Pounds of Chemical to the Square Rod	Percentage Eradication																	Percentage of Eradication Over the Winter
	Field No.1 Gravelly Loam Sprayed June 25			Field No.2 Clay Loam Sprayed July 9			Field No.3 Silt Loam Sprayed August 26			Field No.4 Gravelly Loam Sprayed September 16			Field No.5 Silty Clay Loam Sprayed, Oct.26					
	Oct.4 1929	May 11 1930	Aug.17 1930	Oct.15 1929	May 11 1930		Oct.18 1929	May 17 1930	Aug.10 1930	Oct.18 1929	May 11 1930	Aug.19 1930	May 17 1930	Aug.20 1930				
½	--	--	--	80	98	—	24	66	50	75	86	0	75	60				24
1	75	93	97	96	97	—	33	95	95	94	98	55	98	50				19
1½	--	--	--	90	93	—	39	97	98	50	95	36	76	50				36
2	78	91	99	91	100	—	91	100	99	80	100	73	90	75				13
2¼	75	92	99	80	96	—	84	100	99	92	100	75						16
3	91	99.9	100	90	98	—	86	99	99	90	100	84	91	82				10
4½	87	100	100	99	100	—	93	100	99	92	100	99	96	96				7
6	95	99.9	100	99	100	—	100	100	100	98	100	99	92	88				2
Average Percentage Eradication of each Count	83	95	99	90	97	—	68	94	92	84	97	65	83	71				Avg.% 15

fields in question show a great variability also yet here we have the same degree of eradication, indicating that soil variance is perhaps not directly correlated with the degree of effectiveness of the chemical.

On the other hand, it must be admitted that differences in time of application and stage of growth occur in the first three fields representing a similar percentage kill, as well as in the latter two fields representing the same percentage kill; yet it may be possible that the chemical could display the same effectiveness from the full bloom stage up to a particular time or stage of growth later in the season, after which another degree of effectiveness is portrayed, due largely to the stage of growth the plant is in and its potential difference in ability to react differently to the chemical.

Other data bearing on this point are presented in Table No.2.

It was thought desirable to ascertain the progressive effect of the chemical over a period of time disclosing, if possible, a knowledge of whether or not a greater or less kill occurs as time proceeds. It was especially desired to understand the effect, if any, of the winter season. Data allowing the preparation of the above cited table was thus obtained.

In all fields a greater kill is observed in the spring of 1930 than was exhibited in the fall of 1929. The extent of kill, therefore, has increased somewhat(15 per cent) over the winter. During the summer of 1930 opposing results were obtained. On fields Nos. 1 and 3* the percentage kill was increased or remained practically the same over the summer. On fields Nos. 4 and 5 the percentage kill over the summer has markedly decreased. It is interesting to note that the latter two fields are the ones displaying the less favorable results in Table 1.

The fields wherein a decrease in percentage kill occurred over the summer following treatment are the ones treated in the late seed and dormancy

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*Field No.2 was unaccountably burned during the summer of 1930 making correct data of the chemical's effect over this period of time, uncollectable.

stages of the plant's growth, making it appear as if the stage of growth or time when the chemical was applied, had something to do with its ultimate effectiveness. It would be folly to state this as a conclusion, however, for it is realized that the element of soil variance is still present with its possible influence. Moisture conditions, organic matter, content of soils, and other soil conditions may also have an influence.

Additional Tests on Morning Glory

An interesting condition was obtained on a sixth field of morning glory where two applications were made on all plats with a power sprayer. The first application was applied July 8th and the second July 30th. Treatments in the first application ranged from 1½ to 6 pounds to the square rod; in the second 1½ pounds to the square rod was applied on all plats. The range of treatments from the two applications was 3 to 7½ pounds.

On the 36 plats treated the percentage kill ranged from 99 to 100. Approximately 300 plants represented the number on the whole treated area (45 square rods) where before treatment a complete mat of morning glory existed.

The interesting feature brought out in the work on this particular field was a difference in resistance of different plants to the chemical. A plant relationship of morning glory, asparagus, and Indian hemp(Apocynum cannabinum) existed on the field before treatment; after treatment only the asparagus(Fig.3) and Indian hemp remained, for the morning glory was almost completely eradicated.

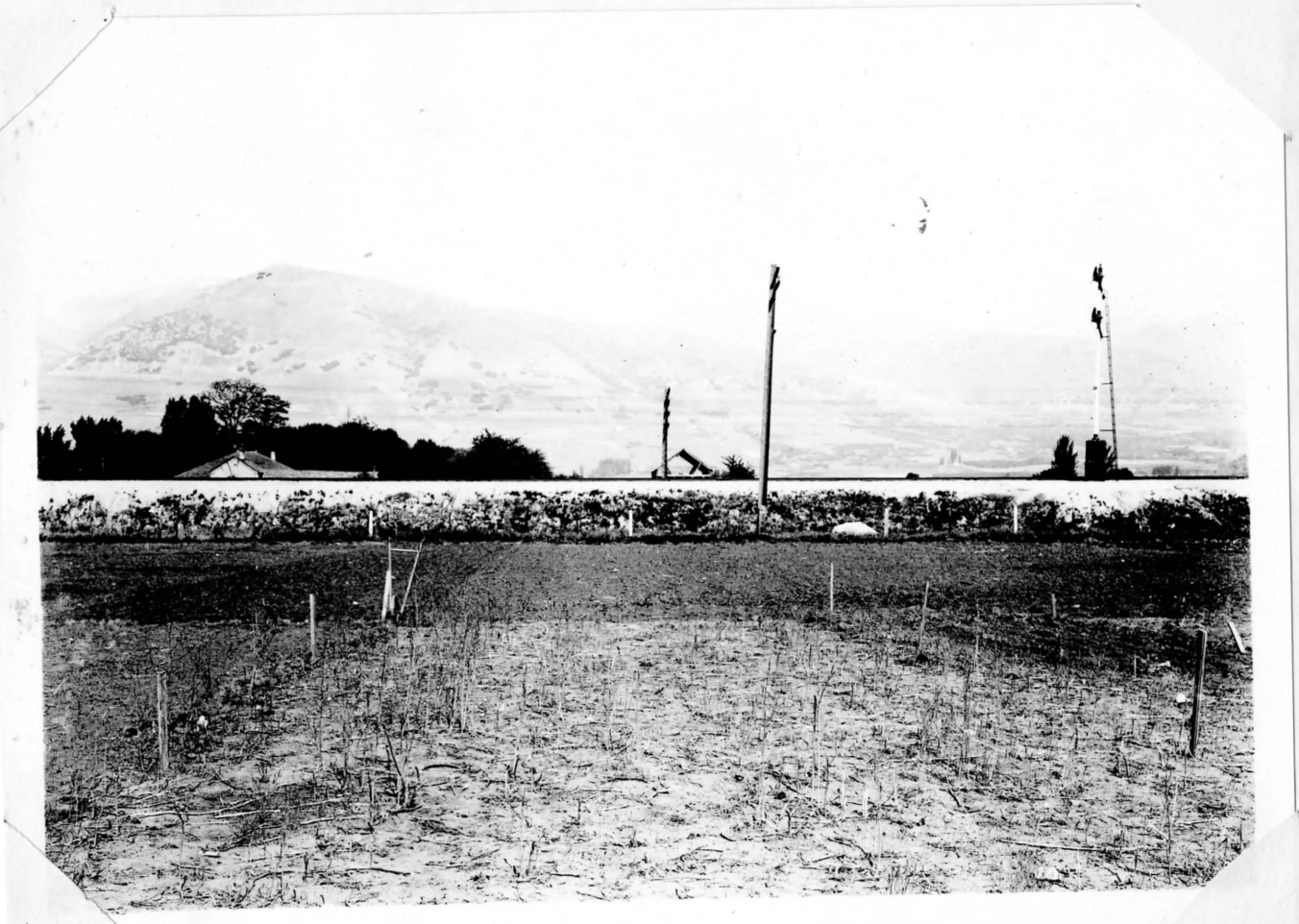

Fig.3.- Showing the growth of asparagus(June, 1930) on an area which received $4\frac{1}{2}$ pounds of $Ca(Cl\ O_3)_2$ to the square rod in July, 1929. This field was completely covered with morning glory before treatment. It is evident that the morning glory has been practically destroyed; the asparagus however appears to be quite healthy.

EFFECT OF VARIOUS AMOUNTS OF $Ca(Cl\ O_3)_2$ ON RUSSIAN KNAPWEED, (Fig.4) CANADA THISTLE, AND PERENNIAL SOW THISTLE (Fig.5)

The effects are (Table 3) similar to the results on morning glory: as the chemical is increased the percentage of kill increases also but not in proportion to the increase of the former. Here again, the 2-pound applications are very nearly as good as the 6-pound, making the lighter applications, with reference to their relative effectiveness, more economical than the heavy ones.

A 100 per cent eradication was attained only with perennial sow thistle. Two, 3, 4½, and 6 pounds each gave this amount of kill on this weed. Ninety nine per cent eradication was obtained on Russian knapweed and Canada thistle. Although this is a good kill it must be remembered that one healthy weed of this type on a plat represents a potential reinfestation of the field. So the ideal desired, and the one which must be achieved for the solution of the perennial weed problem, is the complete removal of all such plants.

A point showing the comparative resistance of various weeds to the chemical is disclosed in the data of Table 3. The average percentage kill for all treatments on Russian knapweed was 79, for Canada thistle 90, and for perennial sow thistle 88. The latter two weeds, it appears, can be made killed with equal ease, while Russian knapweed may be somewhat more resistant.

TIME OF APPLICATION ON RUSSIAN KNAPWEED, PERENNIAL SOW THISTLE AND CANADA THISTLE

The data here are not exhaustive but it was shown with the treatments made (Table 4) that in some cases the earlier treatments were better than those made in September or October. On perennial sow thistle, 3 pounds applied in July, when the plant was in the vegetative stage displaying 4 to 6 inches of growth from a previous cutting at the time the first crop of hay was harvested, was considerably better than 3 pounds applied in September when this same plant had reached the full-bloom stage. One hundred per cent kill

Fig.4.- Photograph of work on Russian knapweed. In the center of the picture to the right is a check plat, directly opposite this to the left the weed received one pound of $Ca(Cl\ O_3)_2$ to the square rod. In the foreground of the picture, to the left, results of a pound and a half to the square rod is observable, while directly opposite, to the right, is seen the results of 2 pounds to the square rod.

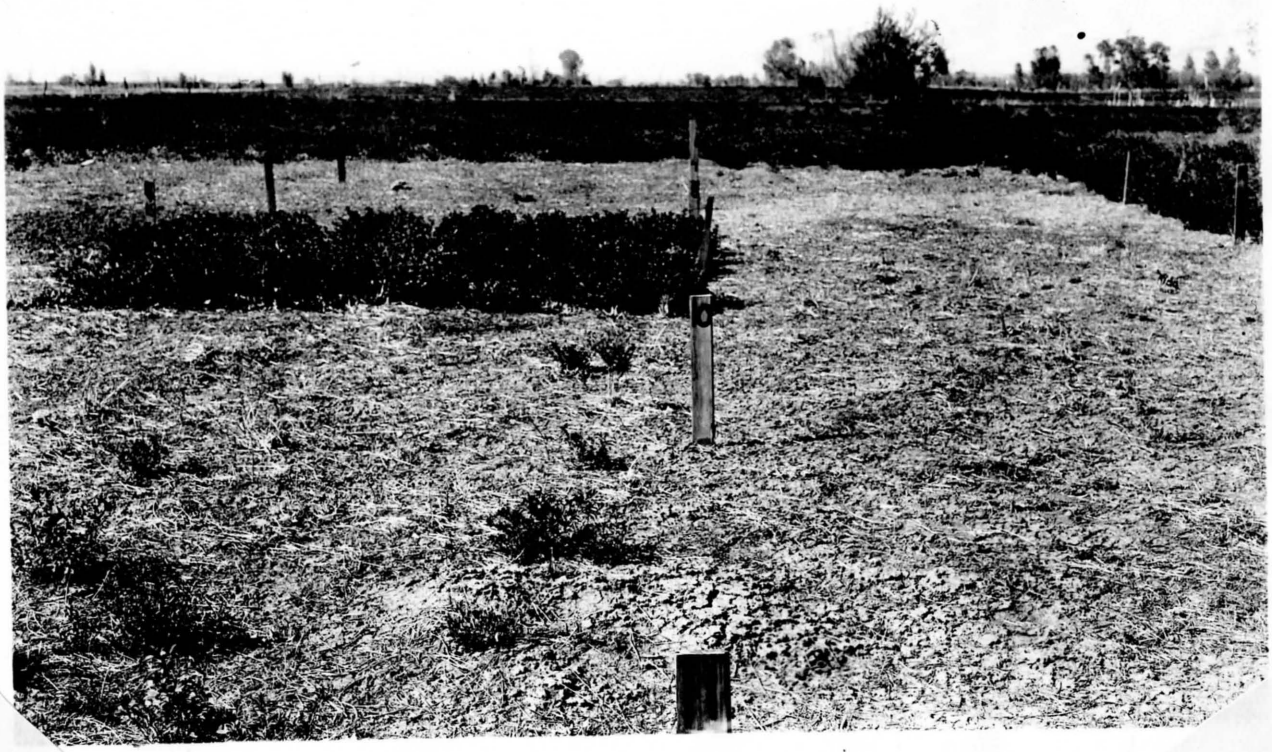

Fig.5.- Here is shown some results of work on perennial sow thistle. Plat No.9 is a check. No.10 is a two-pound application and No.11, representing the area in the foreground to the left, received one pound of the chemical to the square rod. The chemical was applied in the powder form. The area devoid of weeds, to the right of the picture, was under the influence of treatments ranging from 3 to 6 pounds to the square rod.

Table 3. Effect of various amounts of Ca Cl O_3 on Russian knapweed, Canada thistle, and perennial sow thistle

Pounds to the Square Rod	Percentage Kill		
	Russian Knapweed	Canada Thistle	Per Thistle
1½	45	50	40*
1	50	80	97
1½	85	95	94
2	92	99	100
2½	90	98	97*
3	91	98	100
4½	98	99	100
6	99	99	100
Average Percentage Eradication	79	90	88

*Results from one plat

Table 4. Influence of time of application on Russian knapweed, Canada thistle, and perennial sow thistle

Pounds of Ca Cl O3 to the Square Rod	Percentage Kill					
	Russian Knapweed		Canada Thistle		Perennial Sow Thistle	
	August Treatments	October Treatments	August Treatments	October Treatments	July Treatments	September Treatments
1	65	50	80	91		
3	90	85	98	95	100	68

was obtained with the application made in July, while 68 per cent represented the effectiveness of the September application. These percentages are averages of 4 replications in the early and late treatments, respectively.

The difference found in the early and late applications made on Russian knapweed and Canada thistle were hardly great enough to lie out of the range of experimental error. The one approaching significance was a pound application on Russian knapweed made in August and October, the former giving 65 per cent kill and the latter 50. The conclusion in regards to time of application on these three weeds amounts to about this: On perennial sow thistle good evidence is at hand to show the superiority of a July application over one made in September. On Russian knapweed and Canada thistle the differences were not great enough to allow the formation of a conclusion, except perhaps that time of application has little influence on the ultimate effectiveness of the chemical.

COMPARATIVE EFFECTIVENESS OF SODIUM AND CALCIUM CHLORATE ON RUSSIAN KNAPWEED, CANADA THISTLE, PERENNIAL SOW THISTLE, AND MORNING GLORY

Sodium chlorate harbors a fire hazard which is not present to the same extent in calcium chlorate. It is therefore desirable to ascertain the comparative value of the two as weed eradicators. If calcium chlorate is found to be as effective as the sodium salt, it will be the most widely used chemical, and as a result great danger from fire will not exist.

Results of identical treatments of the two compounds indicate(Table 5) that calcium chlorate is practically as good a chemical as sodium chlorate for eradication of the four above named weeds.

The average percentage kill of the calcium chlorate treatments on Russian knapweed was 80 as compared to 91 for the same treatments with sodium chlorate. On Canada thistle and perennial sow thistle both salts gave the same degree of eradication; i.e., 98 per cent on the former and 100 per cent

Table 5. Comparative effectiveness of $Ca(Cl\ O_3)_2$ and $Na\ Cl\ O_3$

Pounds to the Square Rod	Percentage Kill									
	Russian K. Weed		Canada Thistle		Per Thistle		Morning Glory	
	$Ca\ ClO_3$	$Na\ ClO_3$	$Ca\ ClO_3$	$Na\ ClO_3$	$Ca\ ClO_3$	$Na\ ClO_3$	$Ca\ ClO_3$	$Na\ ClO_3$
1	50	65						
1½	65	92	97	97			69	96
3	93	99	98	99	100	100	94	97
4½	98	99	99	99	100	100	98	99
Average Percentage Eradication	79	90.8	98.2	98.5	100	100	87	97

Fig.6.- The above photograph indicates the comparative effectiveness of Na Cl O_3 and $Ca(Cl\ O_3)_2$ for the eradication of morning glory. In the foreground of the picture are two plats which received no treatment, directly back of these Na Cl O_3 was applied at the rate of 3 pounds to the square rod and immediately back of this, to the left of stake No.25, the results of $Ca(Cl\ O_3)_2$ at the rate of 3 pounds to the squnre rod can be observed. The 3 pounds to the square rod of $Ca(Cl\ O_3)_2$ appears to be as effective as 3 pounds to the square rod of Na Cl O_3.

on the latter. On morning glory(Fig.6) the average percentage kill for treatments with calcium chlorate was 87, compared to 97 per cent, average of the same treatments with sodium chlorate.

The two salts on Canada thistle and perennial sow thistle are equally effective. A difference, which is perhaps not great enough to lie out of the range of experimental error, is noted in favor of Na Cl O_3 on morning glory and Russian knapweed. A scrutiny of the data of Table 3 discloses the fact that practically the whole of this difference lies in the weaker treatments. In some of such treatments significant differences are evident. One and one-half pounds of $Ca(Cl\ O_3)_2$ on Russian knapweed and morning glory gave the following respective kills 65 and 69, but the corresponding comparative kills with Na Cl O_3 on the same weeds were 92 and 96 per cent. This is the only significant indication in the experiment which would hint to a superiority of sodium chlorate over calcium chlorate for the eradication of these four specific weeds.

METHOD OF APPLICATION(Fig.7)

Two points are involved in this question: First, a possible influence on the effectiveness of the chemicals, and second, a possible saving of expense if negative results are obtained from work on the first point, for in such a case the most economical method could be wisely recommended.

Information bearing on this point is seen in Table 6, which discloses the fact that method of application has practically no influence upon the effectiveness of the chemical. In the case of Russian knapweed 1½ pounds of the powder sprinkled dry over the plot appeared somewhat better than 1½ pounds applied in solution with a hand sprayer. On Canada thistle a slight difference the other way is noted. No significant differences are seen in the rest of the comparative treatments. The averages of all treatments under the four different methods involved, i.e., hand sprayer, sprinkling can, applications of powder,

Table 6. Influence of various methods of application

Weeds Involved	Pounds to the Square Rod (Ca Cl O_2)	Percentage Eradication: Hand Sprayer	Sprinkling Can	Applications of Powder	Power Sprayer
Russian knapweed	1½	65	—	88	—
Canada thistle	1½	99	—	90	—
Perennial sow thistle	1½	99	—	94	—
Morning glory	1½	78	—	80	—
Russian knapweed	2	95	—	92	—
Canada thistle	2	99	—	99	—
Russian knapweed	3	93	90	90	—
Canada thistle	3	98	98	—	—
Perennial sow thistle	3	100	98	100	—
Morning glory	3	93	96	95	98
Average Percentage Eradication		92	95	92	98

Fig.7.- A photograph of treatments on Russian knapweed. Plat No.6, in the foreground to the left, received 3 pounds to the square rod of $Ca(Cl\ O_3)_2$ applied with a hand sprayer. Plat No.17, representing the area to the left just back of Plat No.6, received the same amount of chemical, but was applied with a sprinkling can. No difference in the amount of kill can be observed. Plat No.18, representing the area with growth on the left and center of the picture, is a check.

and power sprayer are respectively 92, 95, 92 and 98 per cent.

It is evident from such results that the small differences in kill found under different methods of application, are not anywhere near great enough to lie out of the gamut of experimental error, and cannot therefore be ascribed as due to the factor at issue. Within the range of methods of application employed in this experiment, then, the method of application appears not to influence the effectiveness of the chemical.

CONCENTRATION OF THE SOLUTION(Fig.8)

It was conceded possible that the concentration of the solution could influence the weed killing qualities of the chemical enough to make a knowledge of its activity of great practical value. One concentration, it was admitted, could be absorbed faster by the plant, another perhaps slower but over a greater period of time, each potentially producing the same result or, on the other hand, results of great variance.

Work was done on this factor the results of which show(Table 7) that of the various concentrations tried one was as good as another.

(The same amount of chemical, i.e., 3 pounds to the square rod was used in the three concentrations employed in the experiment.) The average percentage kill from all 1-pound-to-the-gallon applications of $Ca(Cl\ O_3)_2$ on the four weeds was 97; of the $\frac{3}{4}$ pounds-to-the-gallon applications, also 97; and of the $\frac{1}{2}$ pound to the gallon applications, 95. The average of the one-pound to-the-gallon and the one-half-pound-to-the-gallon application of sodium chlorate was 99 per cent for each. The three concentrations produced an almost identical degree of eradication.

Practical value may be derived from the use of these results, for if 3 pounds in 3 gallons of water is as good as 3 pounds in 6 gallons a saving of expense of application will be effected by the use of the former concentration.

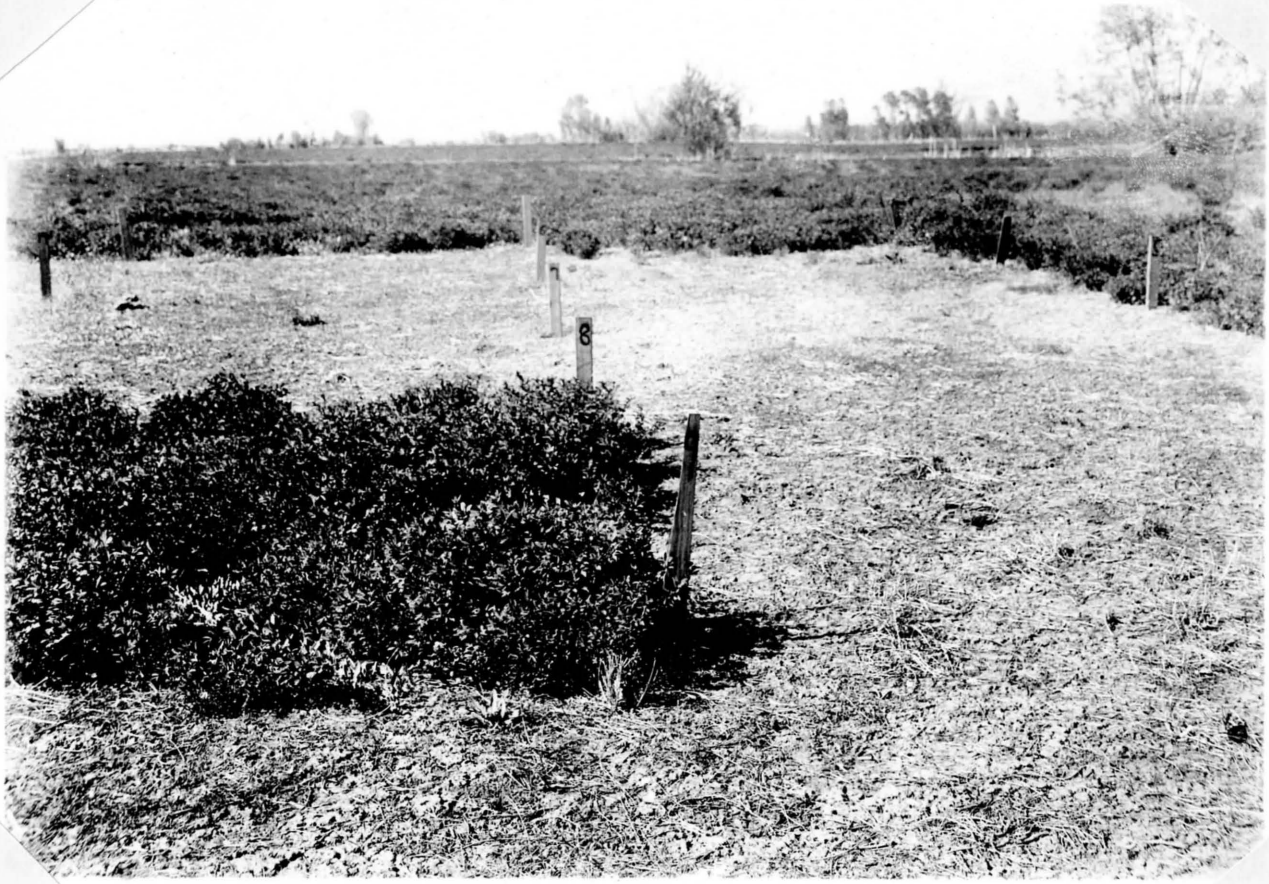

Fig.8.- The area devoid of weeds(perennial sow thistle) to the right of the picture, along with Plat No.6 in the background to the left, includes treatments of three concentrations, i.e., 1 pound to the gallon, $\frac{1}{2}$ pound to the gallon, and $\frac{1}{4}$ pound to the gallon. No difference in effectiveness can be seen in the various concentrations. The same amount of chemical was applied in each concentration.

Table 7. Influence of the concentration of the solution

Concentration of Solution (Lbs. to the Gal.)	Pounds to the Square Rod	Percentage Eradication								Average Percentage Eradication	
		Russian Knapweed		Canada Thistle		Perennial Sow Thistle		Morning Glory			
		$Ca(ClO_3)_2$	$NaClO_3$	$Ca(ClO_3)$	$NaClO_3$	$Ca(ClO_3)$	$NaClO_3$	$Ca(ClO_3)_2$	$NaClO_3$	$Ca(ClO_3)_2$	$NaClO_3$
1	3	93	99	98	99	100	100	97	97	97	99
¾	3	92	--	99	--	99	--	97	--	97	--
½	3	88	99	99	99	100	100	92	98	95	99

No information can be offered as to whether or not concentrations different from the ones used here would influence the effectiveness of the chemical.

EFFECT OF DISTURBING THE WEED BEFORE TREATMENT

Treatments of two and three pounds to the square rod, respectively, were made on morning glory in its normal state of growth compared to the same treatments made after the top growth was cut and removed. With 2 pounds to the square rod a 90 per cent kill was obtained where the top growth was removed compared to 73 per cent where the morning glory was undisturbed. With 3 pounds to the square rod kills of 90 and 86 per cent were obtained on the disturbed and undisturbed areas, respectively.

Three-pound treatments were applied on morning glory after it was plowed in one case, and in another case after it was plowed and manured at the rate of 30 tons to the acre. Results of these treatments were compared to the results of 3 pounds applied on the undisturbed weed growth. Treatment after plowing gave a 96 per cent kill; after plowing and manuring 95, and on the undisturbed growth 86.

The differences found here are not great enough to draw a definite conclusion one way or the other, but they do indicate that disturbances of the manner described herein do not in any way tend to reduce the effectiveness of the chemical.

EFFECT OF A GIVEN AMOUNT OF CHEMICAL APPLIED IN SEVERAL APPLICATIONS COMPARED TO THE SAME AMOUNT APPLIED IN ONE

The average percentage kill(Table 8) of the one-pound-in-two-application treatments(on the four weeds) was 89, of the one-pound-in-one application treatments, 77. A difference of 12 per cent is noted in favor of the two-application treatments. The greatest specific response to the two-

Table 8. Influence of a given amount of chemical applied in two or three applications compared to the same amount applied in one

Number of Applications	Pounds to the Square Rod	Percentage Eradication				
		Morning Glory	Russian Knapweed	Canada Thistle	Perennial Sow Thistle	Average Percentage Eradication
2	1	96	75	86	99	89
1	1	94	50	75	90	77
3	3	96			100	98
1	3	97			100	98
2	2	99	95	99	100*	97
1	2	98	92	99	100*	97

*Results from one plat

application treatment was obtained on Russian knapweed where a difference of 25 per cent is in its favor.

Three interval applications of one pound to the square rod each were applied on morning glory and perennial sow thistle in comparison to 3 pounds made in one application. An equal degree of eradication; i.e., 98 per cent was obtained in both cases.

Two pounds per square rod applied in two applications on the four weeds gave an average percentage kill of 97; this same percentage of eradication was obtained with all treatments of 2 pounds applied in one application.

In general, a given amount of chemical applied in two or three applications was no better than the same amount applied in one. This being the case it seems advisable to apply the chemical in one application as a saving of expense will thus be effected.

SOIL EFFECT

This phase of the experiment was not extensive enough to allow the collection of exact yield data on crops planted after treatment. The work done, however, yielded some interesting results.

Practically all crops, planted shortly after treatment, failed to grow(Fig.9).

Some fairly successful results were obtained with certain crops planted the season following treatment. Under this condition, alfalfa on an area which had received 3 pounds to the square rod grew very well, almost totally unharmed. Beans, peas, and corn revealed a slight injury, but all of them matured, giving fairly good yields(Fig.10). Potatoes and turnips showed some effect. Red beets and sugar-beets were seriously injured. Their leaves turned yellow and the plants in general failed to show any vigor of growth. Radishes seemed to grow without a great amount of injury. Of the

Fig.9.- The cultivated area in the foreground of the picture was planted to the fall wheat and alfalfa in October of 1929, about 3 months after the field had been treated with the chemical. The photograph was taken in the spring of 1930. As shown in the picture, the plants failed to grow.

Fig.10.- Photograph of crops planted on a treated morning glory patch. These crops were planted the spring of 1930 on an area which had been plowed and treated with 3 pounds to the square rod of $Ca(Cl\ O_3)_2$ in October, 1929. To the left of the picture will be seen the growth of the various crops, corn, wheat, oats, barley and beans, on the treated area. To the right is seen the growth of these same crops on a check plat, or untreated area. The striking thing represented here is the extent to which the corn is stunted by the morning glory growth on the check plat. It is shown that the weed is more damaging to crops than the chemical.

small grains, oats showed the greatest resistance, with wheat and barley following in the order named. Barley seemed to be rather seriously affected, especially its early vegetative growth.

On the heavier applications, all crops were more seriously injured by the chemical.

The significant point, revealed in this work, it seems, is that these particular chemicals, Na Cl O_3 and calcium chlorate, can be used for weed eradication without a grove and lengthy impairment of the soil for crop production.

SUMMARY

1. The experiment was carried out on nine weed patches(six morning glory, one Canada thistle, one perennial sow thistle, and one Russian knapweed), in three important agricultural counties of Utah.

2. Definite experimental standards were adhered to throughout the course of the work. Replication work was carried out. Check plats were employed and the data were collected on a scientific basis. The plan of experiment was based upon a number of specific problems, the results of which are related in the continuation of this summary.

3. It was found impossible, from the one season data of this experiment, to state a specific amount of chemical which would, under all conditions, insure complete eradication of morning glory, Russian knapweed, perennial sow thistle or Canada thistle.

4. Complete eradication of morning glory was effected on certain fields with treatments of 4½ and 6 pounds to the square rod, and on perennial sow thistle with as low as 2 pounds to the square rod. A complete eradication of Russian knapweed and Canada thistle was not obtained with the highest amount of chemical used, i.e., 6 pounds to the square rod.

5. The 2-pound-to-the-square-rod applications were nearly as good

as the 6-pound treatments.

6. A greater percentage kill over the winter occurred in the lighter treatments than in the heavier ones.

7. In some cases it was found that fall applications were not as effective as earlier treatments.

8. Morning glory growing with asparagus was almost completely eradicated, with applications of from 5 to 7½ pounds to the square rod, while the asparagus was almost totally unharmed.

9. Calcium chlorate appeared to be practically as effective as sodium chlorate.

10. The concentration of the solution within the range of concentrations tried in this experiment, i.e., 1 pound to the gallon, ½ pound to the gallon, and ¼ pound to the gallon had no influence on the effectiveness of the chemical.

11. Applying the chemical in the powder form or in solution with a hand sprayer, power sprayer, or sprinkling can gave equal results.

12. The application of the chemical all at one time gave as good results as applying the same amount at two or three intervals throughout the summer.

13. Plowing the weed under or the temporary removal of its top growth before treatment did not decrease the effectiveness of the chemical.

14. The chemical did not produce a lengthy impairment of the soil for crop production.

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